AD-A061 953 AERONAUTICAL SYSTEMS DIV WRIGHT-PATTERSON AFB OHIO F/G 17/7
ALTERNATIVE TERRAIN FOLLOWING SYSTEM CONCEPTS, (U)
NOV 77 H J MCGLYNN

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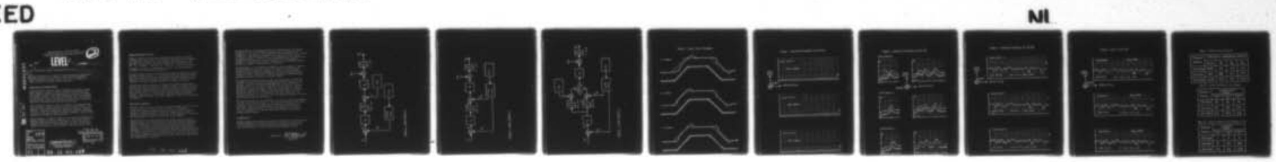

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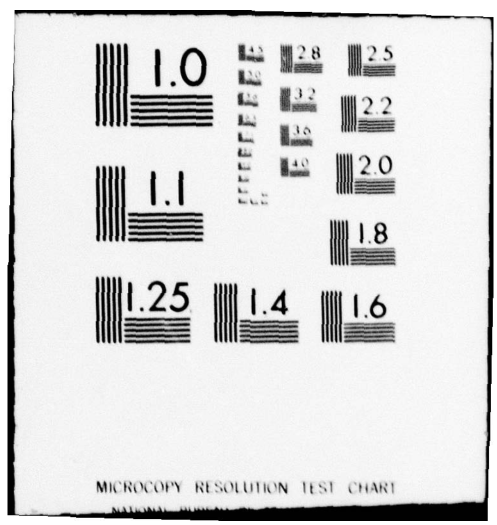
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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

LEVEL II

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MEMO ENFTC

(11) Nov[redacted]77 (12) 12 p.

(6) SUBJ: Alternative Terrain Following System Concepts,

(10) H. J. McGlynn

Three

This memo summarizes the results of an investigation of alternative terrain following system concepts. Three system concepts were evaluated during this study; each of the systems is based on a radar altimeter for sensing terrain clearance. evaluated, each The first concept

DESCRIPTION OF SYSTEM CONCEPTS

System Concept A, shown in figure 1, develops an inertial altitude rate command in response to errors in terrain clearance altitude. This command is limited and summed with the actual rate of change of inertial altitude. The normal acceleration command is generated in response to errors in the inertial altitude rate. This command must be limited in order to maintain the vehicle within aerodynamic, structural, and engine-inlet distortion constraints. The second concept

System Concept B, shown in figure 2, develops a clearance altitude rate command in response to errors in the clearance altitude. This command is limited and summed with the rate of change of clearance altitude. The normal acceleration command is generated in response to errors in the rate of change of terrain clearance. System Concept B describes a frequently used control law. The third concept

System Concept C is shown in figure 3. This concept incorporates the damping feedbacks of System A and System B. Both control laws are executed simultaneously and the most positive normal acceleration command is selected for control purposes. The most positive logic scheme assures smooth switching from one control law to the other.

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LINEAR PERFORMANCE ANALYSIS

System A requires an error in clearance altitude in order to sustain a steady climb rate or dive rate. A positive (or low) error is required for climbs and a negative (or high) error is required for dives. The magnitude of the static error can be defined for a terrain of slope X by $h_e = V\sin X/K_1$. For flight at .7 Mach ($K_1 = .4335$) and a slope of 5 degrees, the offset is approximately 155 feet. The linear behavior of System A is illustrated in figure 4a.

The use of radar altimeter rate feedback in System B eliminates the static offsets observed in System A. For a terrain following vehicle following the exact terrain profile, the terrain rate error will nominally be zero. This will be true even though large inertial climb or dive rates may be required. The linear response of System B is shown in figure 4b.

In the linear sense, System C will behave like System B during pullups and like System A during descents. During a climb at the exact set clearance System B will command zero incremental load factor, whereas System A will command a pushover because of the positive climb rate occurring with zero altitude error. The most positive command would be generated by System B. The reverse is true during a dive where System A generates the most positive command. The linear response of System C is illustrated in figure 4c.

NON-LINEAR PERFORMANCE

The rate limiter in System A and on the inertially damped loop of System C can be set to limit the actual rate of descent. This permits a controlled descent towards the base plain of the terrain. The rate limiter in System B and on the terrain rate damped loop of System C defines the maximum allowable closure rate to the commanded set clearance; the actual rate of descent of the aircraft is not limited.

The performance of System A, System B, and System C was evaluated by simulation over three terrain profiles: Rug Head, CAL6201, and ASD4135. Certain relevant statistics for these terrain profiles are presented in Table I. Rug Head is a relatively flat terrain from southern Georgia, CAL6201 is a moderate rolling terrain from southwestern Pennsylvania, and ASD4135 is a moderate to rough terrain from north central Pennsylvania. The digital simulations were all conducted using a commanded Mach number of .65 for a typical terrain-following vehicle. The terrain rate limiter and the altitude rate limiter were set to a 100 ft/sec dive limit but were left unrestricted for pull-ups.

The performance of each system over the flat terrain profile is presented in figure 5. All of the systems displayed essentially identical performance over this profile. The simulations were conducted at a set clearance of 500 feet. The maximum undershoot of set clearance for each system is listed in Table II. Table III lists the maximum height that the vehicle exceeded the set clearance plus the peak elevation in the immediate vicinity of a dominant peak. This is a measure of the ballooning tendency and can be related to the probability of detection.

The performance of each system over CAL6201 is shown in figure 6. Observe the low undershoot of System A on the front side of the hills and the relatively steep letdown and undershoot of System B on the backside of the hills. System C appears to demonstrate the most favorable characteristics of System A and System B. Note the significantly smaller maximum undershoot recorded for System C over this terrain.

The comparative performance over a rough terrain profile is illustrated in figure 7. System B displays exceptionally poor performance over this terrain. System C recorded a maximum undershoot of only 416 feet in contrast to 612 feet for System A and 1070 feet for System B. Although the overshoot of set clearance is lower for System A than for System C, this must be evaluated in terms of the lowest permissible set clearance and not the 1000 foot set clearance used over this terrain. System C can fly this terrain at a set clearance of 450 feet compared to a set clearance of 650 feet for system A. Thus the absolute overshoot of System A will be higher than that for System C.

The effect of variations in the inertial rate limit on System C performance over ASD 4135 is shown in figure 8. This figure shows that as the terrain roughness increases, performance can be improved by reducing the dive rate limit. Note that the undershoot can be reduced from 416 feet to only 255 by reducing the dive rate limit from 100 ft/sec to 25 ft/sec. It may be desirable to set the dive rate limit with the set clearance during mission planning.

RECOMMENDATION

System C demonstrates superior performance over moderate and rough terrains and performans at least as well as the other systems over flat terrain. It is recommended that System C undergo a more detailed evaluation and that it be considered for use in the advanced development program.

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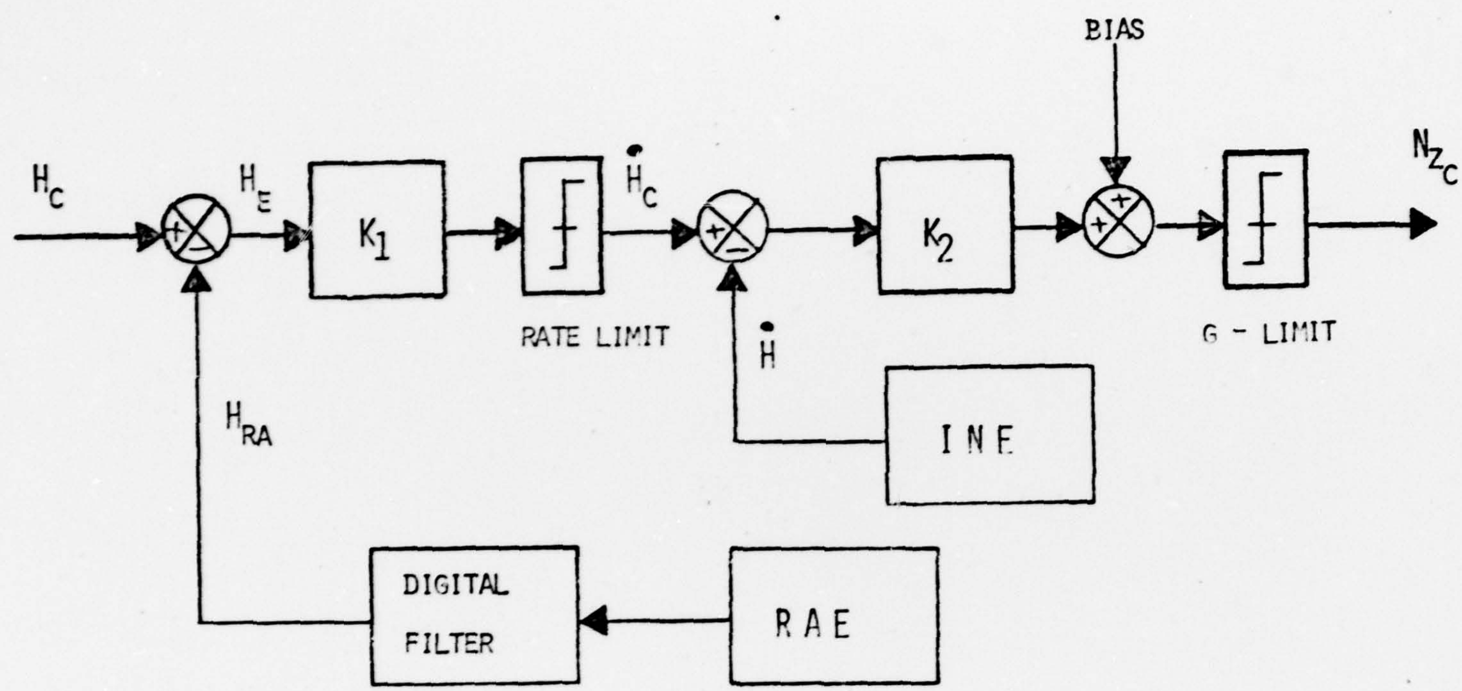


FIGURE 1. SYSTEM CONCEPT A

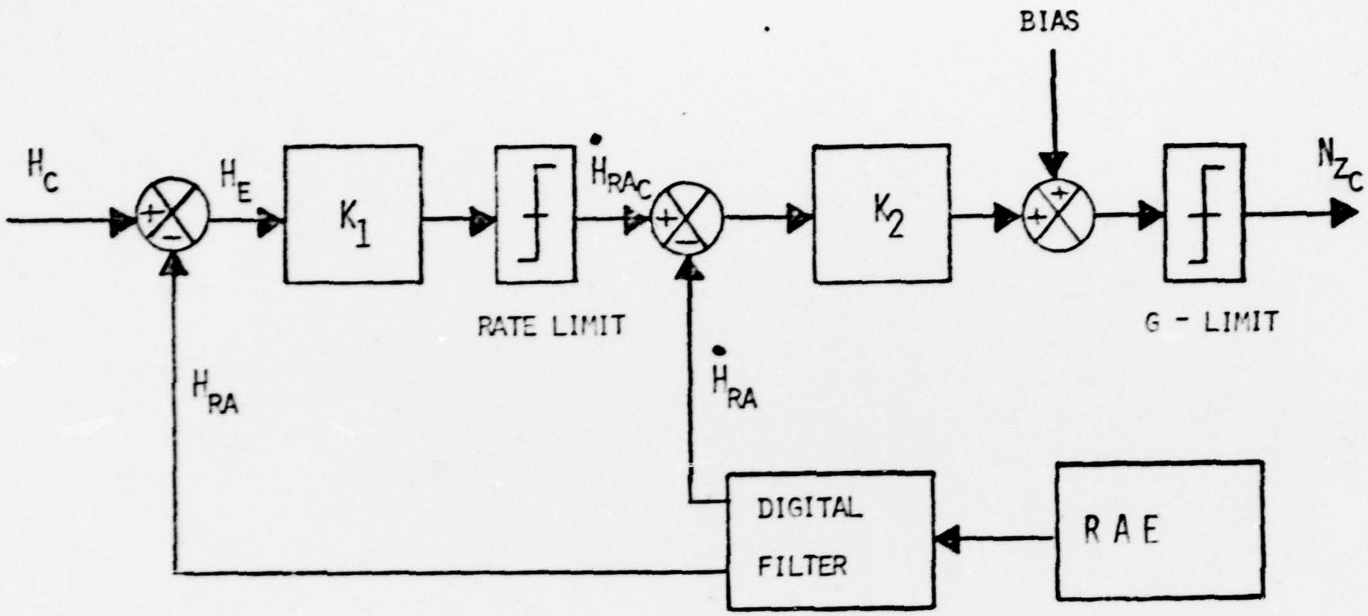


FIGURE 2. SYSTEM CONCEPT B

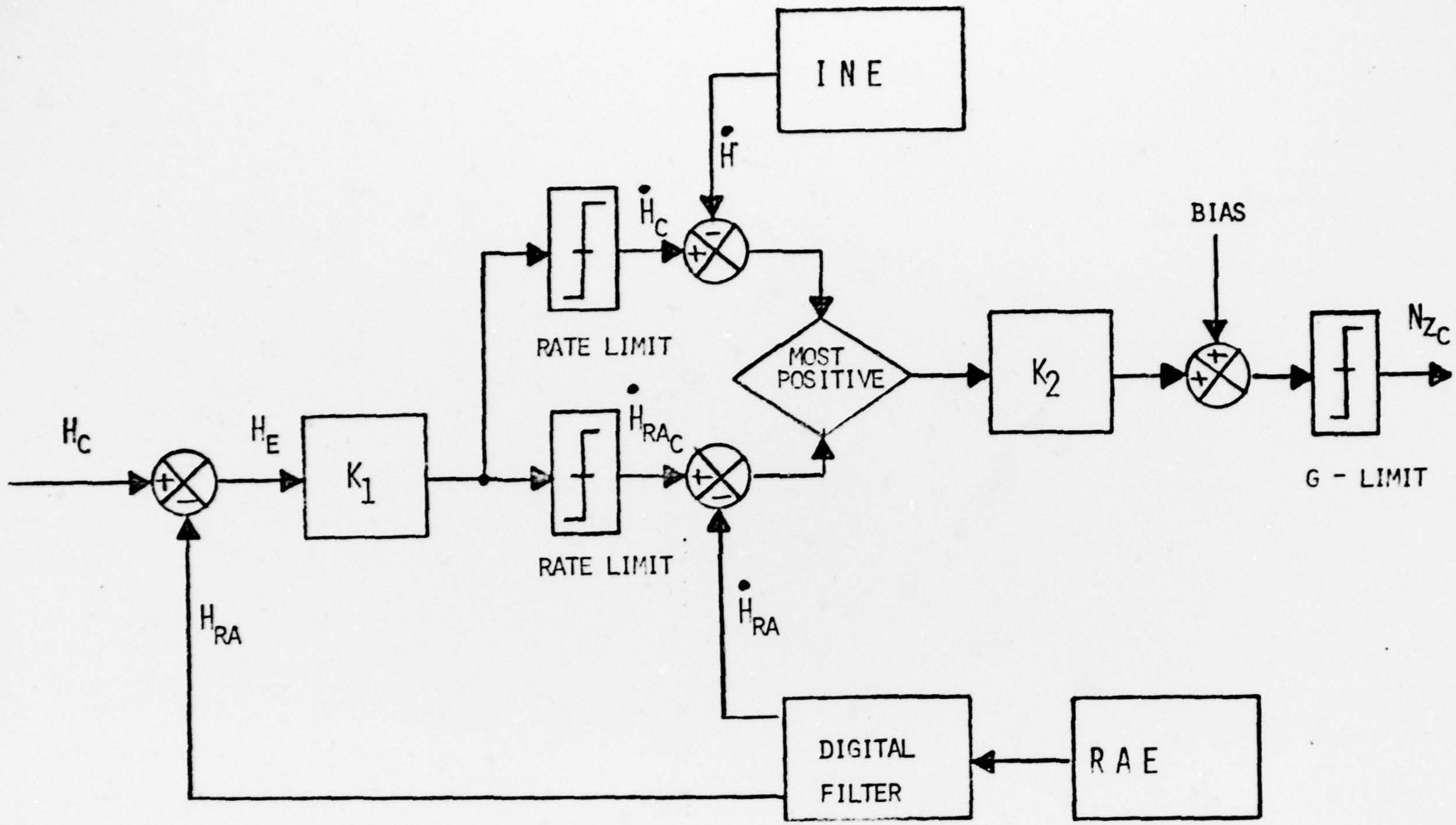


Figure 3. System Concept C

FIGURE 4. LINEAR SYSTEM PERFORMANCE

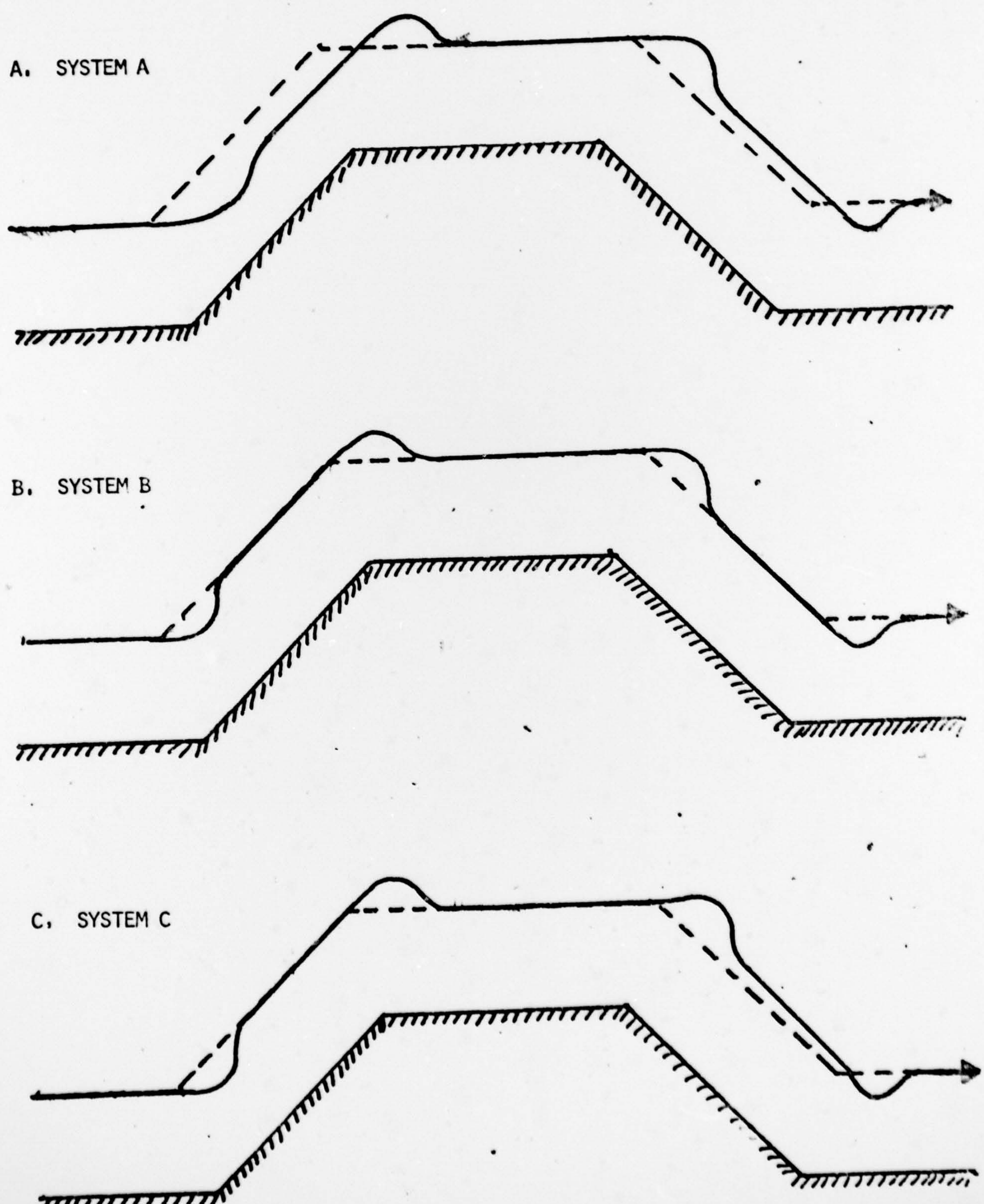


FIGURE 5. COMPARATIVE PERFORMANCE OVER RUG HEAD

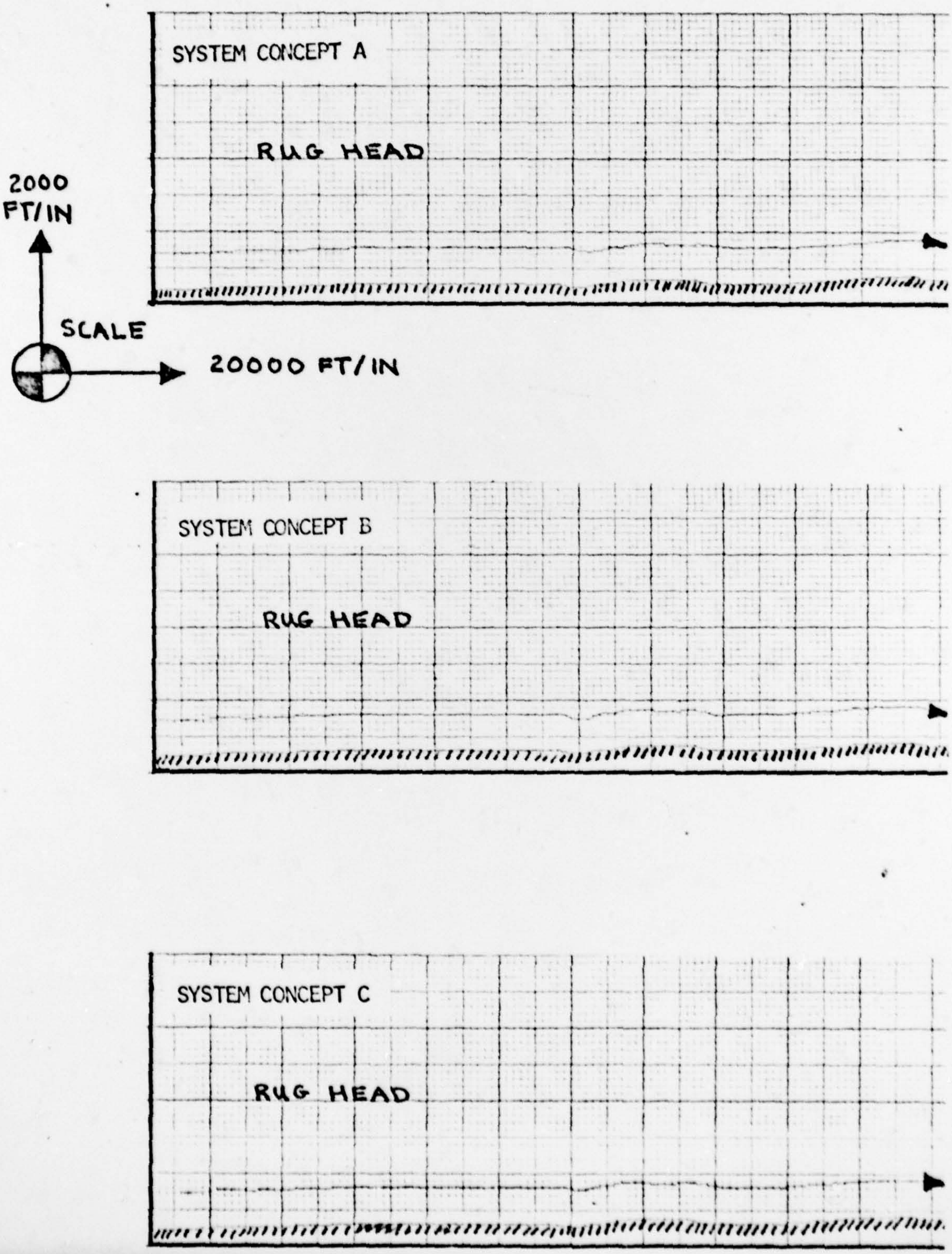
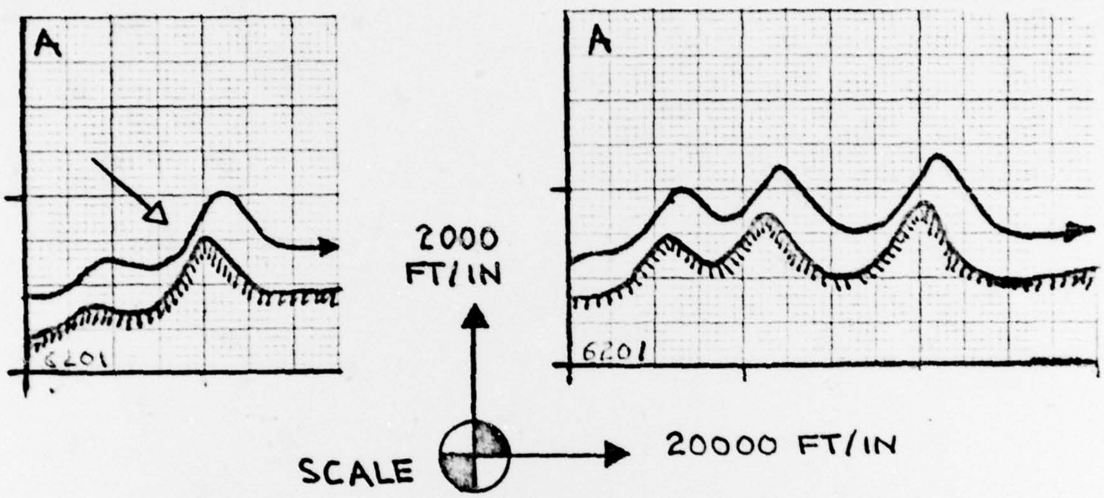
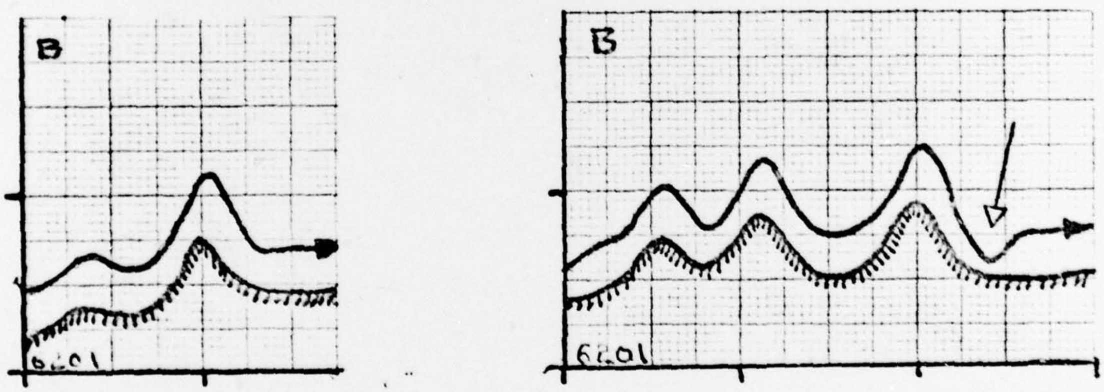


FIGURE 6. COMPARATIVE PERFORMANCE OVER CAL 6201

SYSTEM CONCEPT A



SYSTEM CONCEPT B



SYSTEM CONCEPT C

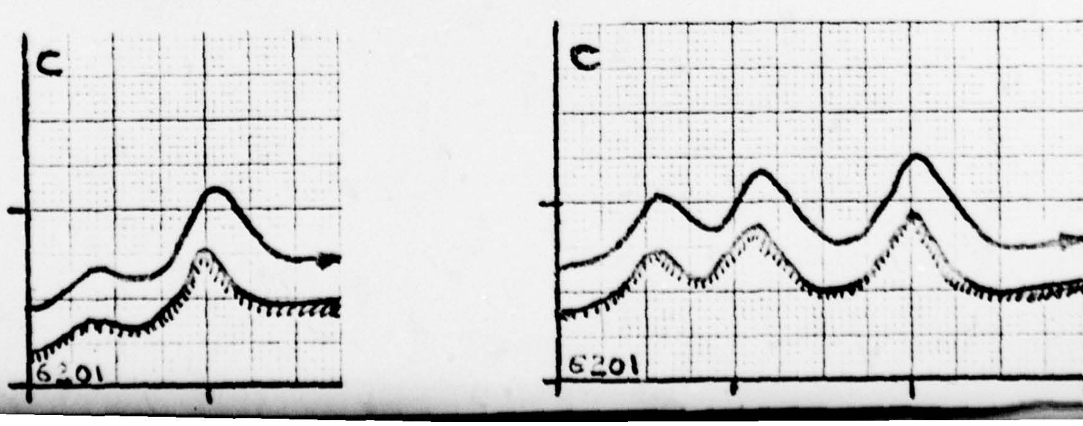


FIGURE 7. COMPARATIVE PERFORMANCE OVER ASD 4135

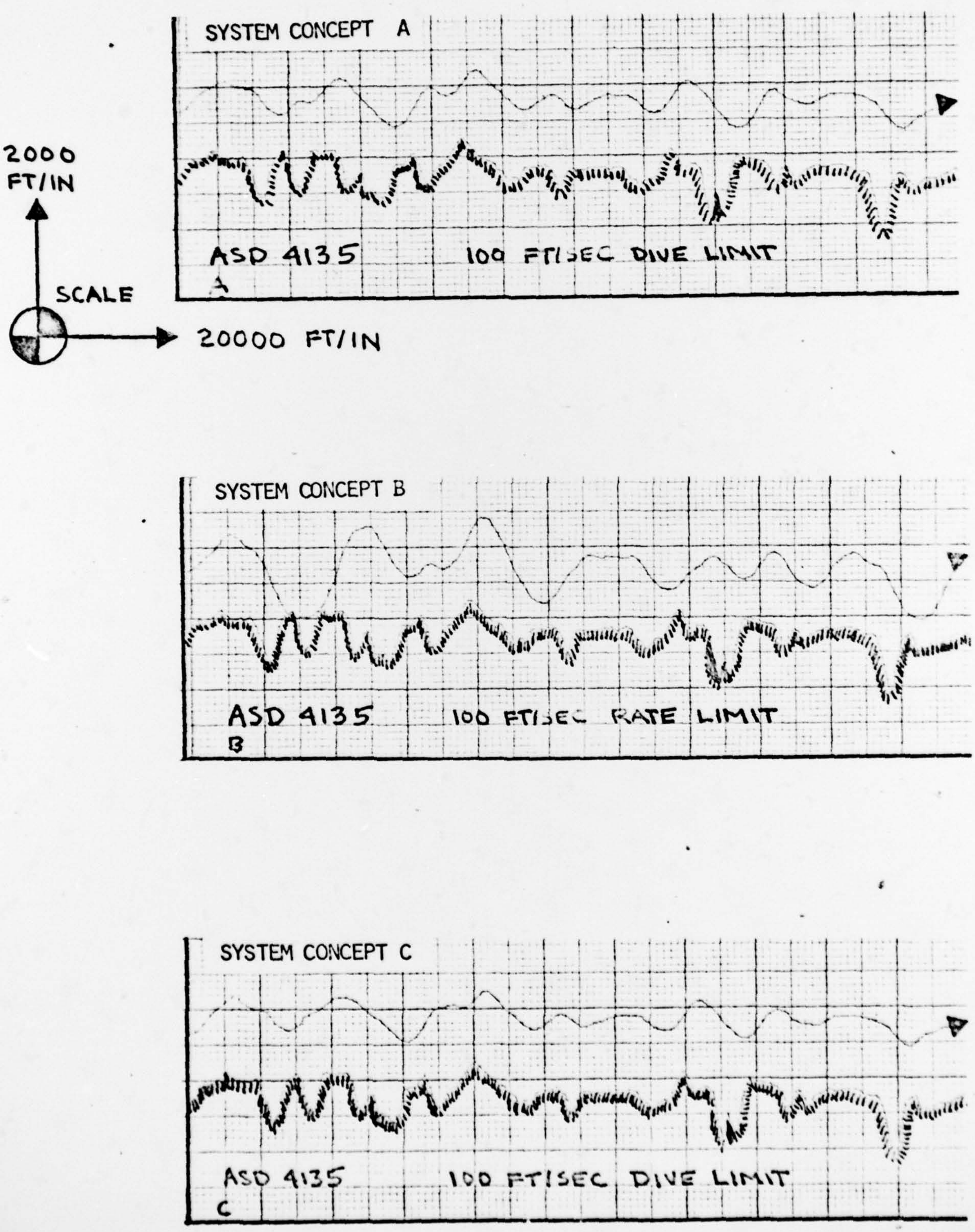


FIGURE 8. EFFECT OF PATE LIMIT

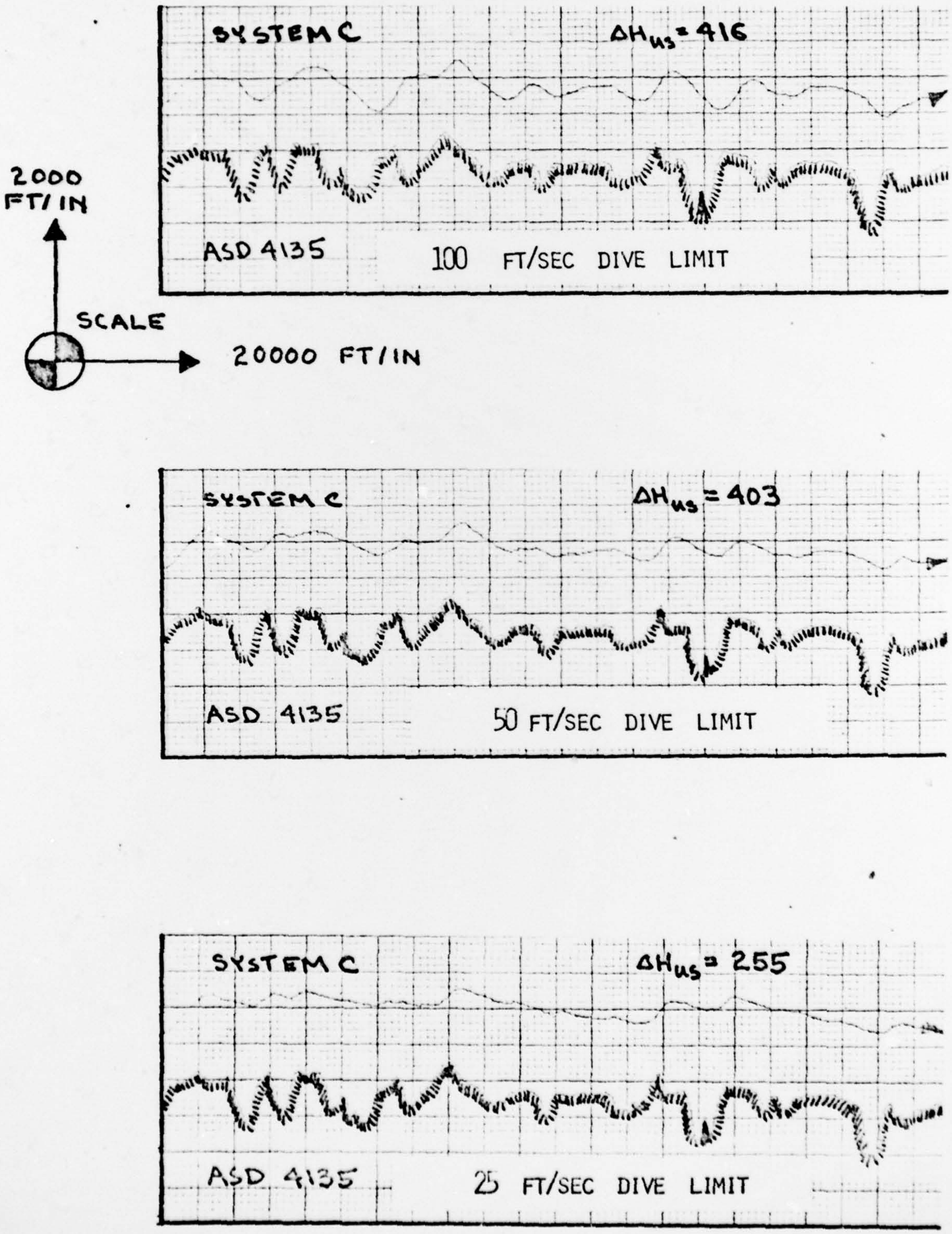


TABLE I. TERRAIN PROFILE STATISTICS

TERRAIN PROFILE	STATISTICAL PROPERTIES (500 FT)			
	MEAN	σ_T	σ_z	σ_W
RUG HEAD	275	52	4.4	3.7
CAL 6201	985	482	31.9	13.7
ASD 4135	1638	339	75.1	122.6

TABLE II. MAXIMUM UNDERSHOOT OF SET CLEARANCE

TERRAIN PROFIE	UNDERSHOOT (FEET)		
	SYSTEM A	SYSTEM B	SYSTEM C
RUG HEAD	52	42	42
CAL 6201	351	334	169
ASD 4135	612	1070	416

TABLE III. MAXIMUM OVERSHOOT OF SET CLEARANCE AT PEAK

TERRAIN PROFILE	OVERSHOOT (FEET)		
	SYSTEM A	SYSTEM B	SYSTEM C
RUG HEAD	1	0	0
CAL 6201	8	203	204
ASD 4135	170	212	208